A Bibliometric Framework to Identify and Delineate Subfields of Research on Tribological Wear

Part One: Can We Identify Fundamental Issues by Clusters of Similar Journals?

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Abstract

This contribution is about the first part of a bibliometric framework to identify new fundamentals in friction and wear in the field of tribology research. The first part covers clustering and mapping of bibliographically coupled journals to delineate subfields of tribological wear. The main objective of the whole study was to identify new theory based approaches and fundamentals on research about wear. The whole framework uses indicators from bibliometric elements about journals and conferences, disciplines, authors' keywords and research fronts extracted from publications. We collected slightly more than 5000 publications of relevant literature for the year 2015. In this contribution we report on structuring of journals and conference proceedings. The cluster analysis and a spring based one dimensional mapping of bibliographically coupled journals delivered some delineated disciplinary subfields like materials, mechanical engineering, dentistry, arthroplasty and machining. Clusters of journals on tribological wear delivered applied research as well as some more fundamental issues. However the analysis did not result in specific clusters of journals about new fundamental research on wear.

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1 Introduction

The delineation of subfields of a broader research field attracted growing attention by the bibliometric community in the last years. We used recent findings in bibliometrics to construct a bibliometric framework to map and delineate research fronts of friction and wear in tribology. The key questions were: What are subfields in research on friction and wear? How can we identify fundamentals and mechanisms of wear by bibliometric methods?

The bibliometric framework was constructed in a way that a comprehensive set of publications could be analyzed from different points of view. First we had to define a search strategy and download a set of relevant publications. The bibliometric part consisted of an analysis of journals and conferences, disciplines, authors' keywords and research fronts by bibliographically coupled publications.

To define a proper search strategy we used the definition and fundamentals in wear from basic publications and textbooks. Jost (1966) first introduced the term tribology in his report of the Committee of the British Department (Ministry) of Education and Science. The term has its origin in the Greek word "tribo": "I ribe". He defined "tribology" as "The science and technology of interacting surfaces in relative motion – and of associated subjects and practices". It is strongly combined with friction, wear and lubrication. Nowadays fundamentals in practice and science deal with primary wear modes: abrasive wear, scratching; adhesive wear, galling, scuffing; fretting and fretting corrosion; erosive wear, cavitation impact, electro – arcing; rolling contact fatigue, spalling, delamination and tribo – corrosion, just to give some examples, see also Wear of Materials (2016).

In this paper we present the first part of the analytic framework: the identification of subfields by bibliographic coupling of journals and proceedings papers.

2 Methodology and data

Building the bibliometric framework as a whole we focused on relational bibliometric approaches using co-occurrence analysis, bibliographic coupling, co-citation and co-authorships. Price (1965) first published a basic concept for networks of publications when linking them directly by common references. Firstly he also introduced the term research fronts for a cluster of similar, bibliographically coupled publications. This method was adopted and is intensively used in the scientometric community nowadays. Boyack and Klavans (2010) examined the performance and accuracy of bibliographic coupling, co-citation analysis and direct citation is the least accurate mapping approach so far. Bibliographic coupling slightly showed better results than co-citation analysis and much better results than direct citation. Schiebel (2012) published a method for bibliographic coupling using a spring model (Kopcsa & Schiebel, 1998) to visualize research fronts by three-dimensional local densities. This methodology will be used to map the different elements of the bibliometric framework.

As a first part of the bibliometric framework we present the analysis of clusters of bibliographically coupled journals. The first work to couple journals was published by Narin, Carpenter and Berlt (1972). They described the interrelationship of scientific journals by direct citations amongst 275 selected journals in mathematics, physics, chemistry, biochemistry and biology. The authors found clear boundaries between disciplinary fields and identified cross disciplinary journals between the different fields. Recently Zhang, Xiaomin and Lili (2016) used journal coupling to study the similarity of disciplinary subjects from the subject-classification system of Chinese library classification.

Our approach in this work is to identify sub fields of tribological wear research on the level of bibliographically coupled journals. We measured the similarity of journals and proceedings by the relative number of common references of publications per journal/proceedings. The similarity grew with the number of common references in relation to the total number of references (Jaccard index). We did not use direct citation because it forces a direct link between two journals and common references are a weaker condition for a link and express better the similarity of the content of the documents published in different journals. We used the BibTechMon Software for the two dimensional positioning with the spring model.

For the collection of documents we used a search strategy defined by a Boolean combination of keywords like wear, material removal, material transfer, surface damage, surface degradation and surface deterioration. The keyword combination was applied with the topic feature of the Web of Science™ Core Collection. Due to the huge number of publications (141,499) we reduced the set of publications to the year 2015 and selected only relevant disciplines (excluding disciplines like neurosciences or psychology or archology, etc.). Applying the search strategy we downloaded 5143 documents for further analysis. The data set included 1000 sources (journals, proceedings of conferences …) and 136,704 different cited references. The journals for this analysis were extracted from the set of documents where the journals were given as a source. We did not use another criterion like disciplines to select the journals. This also means that we did not use all published documents of the journals but only those in the set of our term based search strategy. Detailed information about the search strategy is given in Schiebel (2016).

The most relevant keywords were extracted with a modified TFIDF:

$TFIDF_i = tf_{i,j} * \log(N/n_i)$

with $tf_{i,j}$ as the frequency i (number of publications) of authors' keywords in publications (always 1 per publication) of cluster j, N the number of all publications and n_i the number of publications with keyword i. This definition of TFIDF made it possible to rank keywords by relevance for the clustered sources. The keywords were used to describe the content of the documents published in the journals of each cluster and on the level of the cluster.

3 Results

The research on tribological wear is carried out in different disciplines. The journals with the highest number of publication are "Wear", "Tribology International" and the "International Journal of Advanced manufacturing". They are thematically different and cover a broad spectrum of tribological issues. We find thematically more specific journals for surface and coatings, manufacturing, design and materials but also for chemistry, geoscience, medical issues (arthroplasty and dentistry), polymer science and others.

Additionally to the number of publications the column “Number of References” in table 1 gives the total number of unique and not multiple cited references in publications of the journal from our data set. For example: our data set included 251 publications of the Journal “WEAR” with a total number of 6881 cited different references.

Table 1: Journals for research on wear (tribology) by number of publications and cited unique references (not citations) in the year 2015

Journal	Number of Publications	Number of References
WEAR	251	6881
TRIBOLOGY INTERNATIONAL	172	5442
INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY	169	4082
SURFACE & COATINGS TECHNOLOGY	140	4571
PLOS ONE	104	4593
APPLIED SURFACE SCIENCE	98	3278
TRIBOLOGY TRANSACTIONS	77	2162
RSC ADVANCES	70	2677
MATERIALS & DESIGN	67	2400
TRIBOLOGY LETTERS	67	2258

The references that were cited in publications were used to measure the similarity of journals. Just to demonstrate the clustering of coupled journals table 2 lists the co-occurrence of common references of 5 selected journals. Comparing the number of references of table 1 with the diagonal values of table 2 we find the same values. The highest co-occurring number of common references can be found for the journals “Wear” and “Tribology International” with 711 common references. How to be expected the journal

“Surface & Coating Technology” shows a high similarity to the tribology related journals 4 and 5 but not to “Plos One” and not too much to “The International Journal of Advanced Manufacturing Technology”. This outcome is fully appropriate, because as we will see later Plos One covers a broad number of different disciplines.

In a next step we clustered and mapped journals using the cited references of publications to measure the similarity with the Jaccard index. We expected that the clustering and mapping exercise would deliver different subfields of research on tribological wear and additionally would guide to new fundamentals in research on wear

Table 2: Cross table of co-occurrence of common references on publications in 5 selected journals

ID	Source	1	2	3	4	5
1	INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY	4082		68	58	155
2	PLOS ONE		4593		14	20
3	SURFACE & COATINGS TECHNOLOGY	68		4571	298	301
4	TRIBOLOGY INTERNATIONAL	58	14	298	5442	711
5	WEAR	155	20	301	711	6881

The results are shown in figure 1 and 2. Figure 1 shows a circular representation of a cluster dendrogram (for the method of circular dendrograms see for example: How to … 2016).

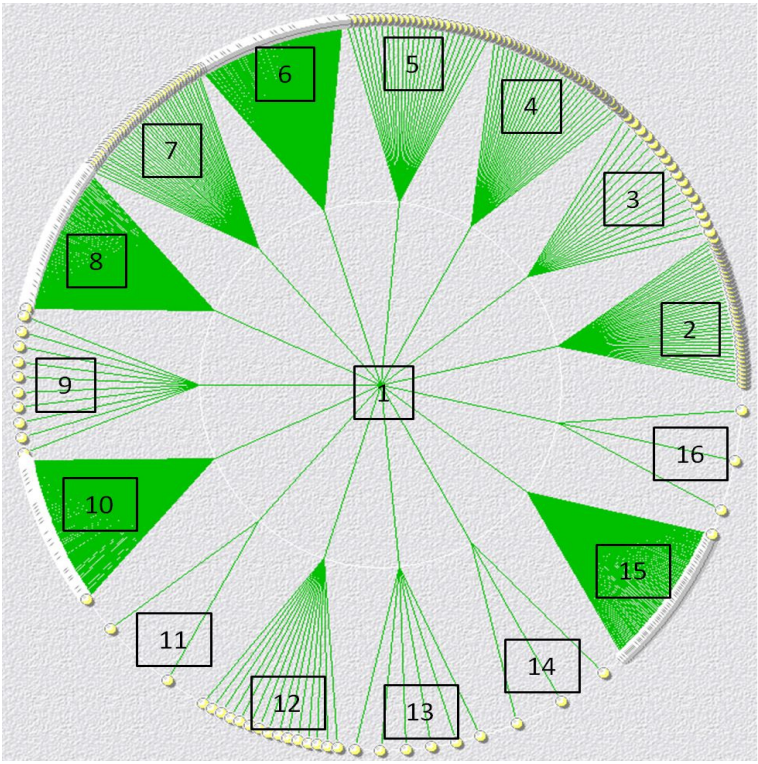

Fig. 1 Circular dendrogram of bibliographically coupled journals, Pearson agglomeration of Jaccard indexes, Ward linkage. The bubbles are the journals, "1" is the root and the numbers correspond with the identified clusters at the level of 15 selected clusters. Software: BibTechMon.

The clusters were calculated by the Pearson Correlation of the Jaccard index and the Ward agglomeration method. The dendrogram was cut at a level of easy to handle 15 clusters. This number was selected after trying different levels and numbers and reading the most relevant keywords ranked by the TFIDF. The selected clusters offered a high number of not "the same" keywords and a list of thematically consistent keywords per cluster. The name of a cluster was formally given by the journal with the highest number of publications.

Figure 2 shows a map of agglomerations of the journals calculated with a spring model. Journals in the same cluster of the cluster analysis were marked with the same color and the size of the bubbles represents the number of references cited in publications of each journal. Clusters of journals with the disciplines tribology, material science and mechanical engineering (2, 4, 5 and 6) are overlapping and located in the northern part of the map.

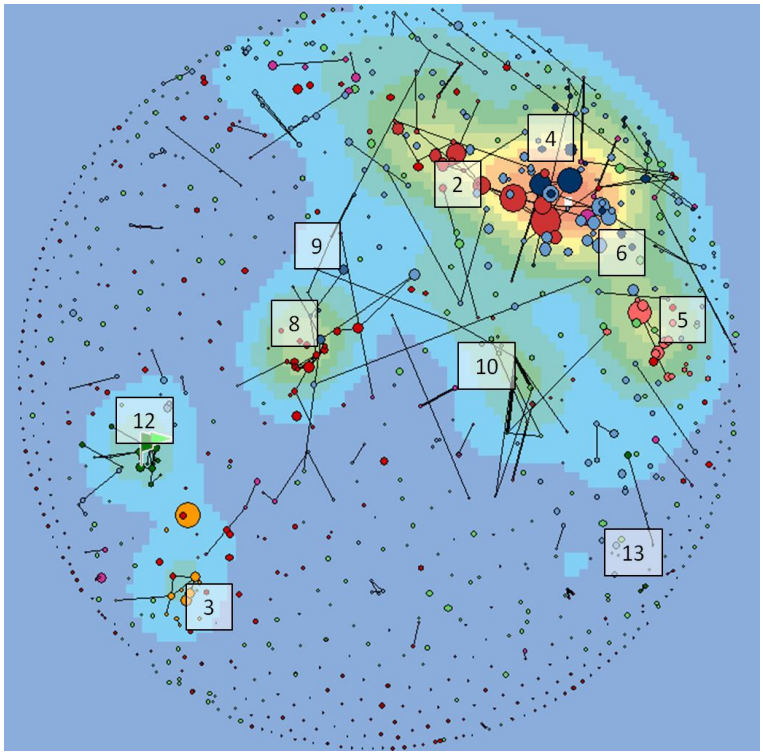

Fig. 2 2-dimensional mapping of bibliographically coupled journals, local distribution, positioned by a spring model, size: number of references, heat colors: local distribution of journals weighted by similarity. The numbers correspond with the cluster analysis and the identified clusters of journals. Software: BibTechMon.

Cluster 2 is formed by the journal "Wear", by journals with "Tribology" in the title, materials and other mechanical engineering issues. We find publications on sliding wear, boundary lubrication and graphene as an emerging lubricant. Metal matrix composites together with research on wear resistance, micro-hardness and corrosion resistance are research issues of journals of Cluster 4.

Cluster 5 is a set of coupled journals related to manufacturing processes and tools. Research work in this cluster covers material removal, tool wear, surface roughness and cutting forces. The last cluster in this field is cluster 6. This is a huge cluster of 228 residual not bibliographically coupled journals from the materials and mechanical engineering area. The publications in this field deal with wear resistance tribology, mechanical property and corrosion what are issues of more general kind in tribology.

Clusters 3, 8 and 12 show a sharp delineation and are of different kind of disciplines than the main, big area mentioned above. Cluster 3 includes the journals Plos One, BMC Public Health, Medicine and Science in Sports and Exercise. It covers research on physical activity accelerometers and is not relevant for tribological wear because the documents matched with the term wear in the sense of people wearing accelerometers.

The cited references of the cluster "Plos One" couple additionally to tooth wear and dentistry that again fits with our field. This leads us to cluster 12 with journals like Archives of Oral Biology and Journal of Dentistry that cover publications on dental erosion, tooth wear and fluoride from medicine. Cluster 8 is formed by journals for total hip and total knee arthroplasty, biomechanics, prosthesis, polyethylene and biomaterials: Journal for Arthroplasty, Journal for Biomechanics and Acta Biomaterialia. Cluster 9 is close to cluster 8 and forms a link to the materials and engineering fields. It represents research on wear and lubrication of polymers and biomaterials, surfaces and interfaces and is covered by the following journals: Journal of Applied Polymer Science, Journal of Biomedical Materials Research Part B – Applied Biomaterials and Polymer Journal. Not mentioned clusters are spread over the landscape of figure 2

The journals of cluster 7 are spread over the thematic landscape and cover different issues on material research. With 281 Journals cluster 10 is the largest one and the journals are also spread over the thematic landscape. It does not represent a delineated field. Cluster 15 covers all remaining journals that are not coupled with each other by references. Cluster 11 and 14 are very small ones. Cluster 13 covers different journals: Mathematical Problems in

Engineering, Mechanism and Machine Theory as well as Minerals Engineering.

Table 2: Clusters of journals for research on wear (tribology), the name of each cluster is the journal with the highest number of references within the cluster, three most relevant authors' keywords measured by the TFIDF are listed in the last column

No.	Cluster Name (Number of Sources)	Keywords
2	WEAR (37)	sliding wear, wear testing, coundary lubrication
3	PLOS ONE (16)	physical activity, accelerometers
4	SURFACE & COATINGS TECHNOLOGY (29)	wear resistance, corrosion resistance, micro hardness
5	INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY (26)	tool wear, surface roughness, cutting force
6	MATERIALS & DESIGN (228)	mechanical property, composite, corrosion
7	JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE (44)	corrosion and wear, Scanning Electron Microscopy (SEM), fatigue
8	JOURNAL OF ARTHROPLASTY (152)	total hip arthroplasty, polyethylene, total knee arthroplasty
9	JOURNAL OF APPLIED POLYMER SCIENCE (10)	wear and lubrication, polyolefins, degradation
10	JOURNAL OF MANUFACTURING SCIENCE AND ENGINEERING-TRANSACTIONS OF THE ASME (282)	absorption, nanocomposite, residual stress
11	MATERIALS CHEMISTRY AND PHYSICS (2)	composite material, nitrides, chemical synthesis
12	ARCHIVES OF ORAL BIOLOGY (15)	dental erosion, tooth wear, enamel
13	MATHEMATICAL PROBLEMS IN ENGINEERING (6)	Discrete Element Method (DEM), breakage, slider-crack mechanism
14	INTERMETALLICS (3)	metallic glass, solid-solution hardening, solid-solution hardening
15	INTERNATIONAL JOURNAL OF EARTH SCIENCES (147)	residual cluster, many different journals, no consistent keywords

4 Conclusions

In the first part of the application of a bibliometric framework to analyze subfields and research issues in tribological wear, we used the bibliographic coupling of journals that were identified by a set of documents collected with a string based search in Web of Science™. The coupling was defined by common references in published documents on the level of the journals. We clustered the journals and calculated a two dimensional map where we positioned the journals due to their similarity defined by the Jaccard Index of the co-occurring references. The cluster analysis revealed some sharply delineated clusters in materials research, mechanical engineering, surfaces and composites on one hand. Wear is also subfield that consists of dental wear, arthroplasty, earth sciences and machining and tooling. In addition to the cluster analysis the two dimensional heat map of similar journals shows the compactness of the clusters and visualizes the content motivated relatedness of groups of journals. It was also used as a graphical retrieval tool to list keywords for each cluster.

We can conclude that also in research on wear Bradfords' law is valid and that the "core documents" would occur in journals with the highest number of publications. To easy identify new fundamentals in wear it would have been helpful to identify one or more clusters of journals that just cover such new fundamentals on wear. But it wasn't what a limitation of the presented approach is. The conclusion is that we have to look closer inside of the publications. Fundamental issues for wear should be found in Cluster 2 named by the journal "WEAR", in cluster 4 named by the journal "SURFACE & COATINGS TECHNOLOGY", cluster 6: "MATERIALS & DESIGN", cluster 11: "MATERIALS CHEMISTRY AND PHYSICS" and cluster 13: "MATHEMATICAL PROBLEMS IN ENGINEERING"

In future work we will compare the results to maps and clusters of disciplines, networks of authors and affiliations, research fronts based on bibliographically coupled publications as well as knowledge bases of co-cited references.

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